INITIAL FEASIBILITY EVALUATION OF CONSTRUCTED WETLANDS TO TREAT FLOWS IN WILSONS CREEK

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EXECUTIVE SUMMARY

In order to address water quality issues in Wilsons Creek (also referred to as Wilson or Wilson's Creek) near Springfield, Missouri, the City proposed five sites for the potential creation of treatment wetlands. Constructed wetlands have been widely and successfully used for treatment of stormwater runoff, base flow, and municipal/industrial wastewater effluent. Consequently, the Springfield Public Works Stormwater Division (SPWSD) retained Wright Water Engineers, Inc. (WWE) to perform an initial engineering feasibility study. The purpose of this evaluation is to identify and evaluate potential "fatal flaws" with the use of constructed wetlands for water quality improvement in Wilsons Creek, evaluate the potential for improvement in receiving water quality, and to present conceptual design considerations and recommendations.

WWE evaluated wetlands constructed to treat base flow only, storm flow only, or a combined system capable of handling base and storm flows. WWE's overall initial finding is that there is good potential for the successful creation and maintenance of wetlands at the five subject sites (shown on Figure 1, General Location Map and Figures 2-6 for individual site maps), and that these wetlands could improve both base flow and wet weather water quality in Wilsons Creek. On an annual basis, and relative to the three most upstream wetland sites from Wilsons Creek at the U.S. Geological Survey (USGS) Springfield gauge, conceptual calculations indicate that the wetlands could remove about 16 percent, or 2,200 lbs, of the combined annual base flow and stormwater total phosphorus (TP) load.[1]

No engineering fatal flaws have been identified based upon the available data. Additional data needs, such as site-specific hydrologic data, refined wet-weather pollutant loading estimates, and

[1] It is important to note that calculations are presented as preliminary estimates only and are based on evaluation of a subset of the total potential wetland area. Removal estimates include consideration of treated and untreated portions of the total flow.

site geotechnical analysis, among others, have been identified in order to augment the current evaluation and determine design(s), which may maximize treatment potential from the wetland sites. Additionally, potentially relevant site constraints have been identified to assure that these conditions are appropriately addressed up-front in the next phase of this project. Further analysis will also contribute to creation of a pilot wetland, which would be used to refine design parameters for additional treatment areas.

The major questions that have been addressed in this initial feasibility investigation are:

- Do the five proposed sites appear feasible for wetland creation from an engineering standpoint, or are there fatal flaws? Preliminary analysis indicates that the five proposed sites are feasible for wetland creation, given the considerations identified below:

    1. Table 1 describes the approximate location and extent of wetland creation sites, as well as general concerns identified at this stage.
    2. Diversion of flows from Wilsons Creek to the wetlands presents certain challenges; however, several options exist. These options may represent significant costs due to excavation or construction of pipelines from farther upstream, but further study is required to provide a realistic assessment.
    3. Site topography will need to be modified to create effective treatment wetlands. Several sites may require significant regrading to promote a flow path parallel to the river.
    4. Site #4 is in close proximity to the Southwest Treatment Plant (SWTP). Potential impacts to the SWTP should be investigated, such as modifying the existing floodplain.
    5. Current access to some of the sites appears limited from aerial photos. Access roads will be required.
    6. Preliminary soil investigations indicate suitable conditions for wetlands creation and establishment, but detailed site investigation is necessary. Interviews with

Springfield City and Greene County staff suggest that on-site soils should be suitable for use as liner material.

7. Some relocation of utilities may be required; however, sites need to be investigated in more detail for a better assessment.

Table 1. Details of Constructed Wetland Sites (See Figures 2-6 for Site Maps).

Site	Location	Estimated Total Site Area (Potential Usable Area for Wetland)	Initial Observations
1	West border is unnamed road (on available maps), east border is Scenic Ave. Wetland creation to north of river, possibly including forested area.	31.5 acres (21 acres usable for wetland creation)	Site topography lends itself well to following natural slope from inlet area to outlet. May require regrade of entire area to reduce slope and special considerations for outlet structure. Treatment area may be limited by amount of earthwork required to utilize entire parcel.
2	North border approximately 0.4 miles north of Bennett St. (Farm Rd 146); south border is Bennett St.	37.3 acres (25 acres usable for wetland creation)	Site area is bisected by intermittent stream. Possible design configurations include relocation of stream discharge or use of only a portion of the area.
3	North border is F.R. 156; south border is James River Freeway.	11.6 acres (7 acres usable for wetland creation)	Steep slopes on either side of the flood plain. Potential impacts to private property on east side. Parcel on south side is only approximately 2 acres.
4	Bounded by James River Freeway on the north and the north end of the SWTP to the south. Wetland creation area on southwest side of river.	28 acres (19 acres usable for wetland creation)	Close proximity to treatment plant. Natural site topography would require significant earthwork/regrading.
5	North border is Farm Road 168; south border is Highway M.	18.6 acres (12 acres usable for wetland creation)	Somewhat steep slopes on east bank. Site area is bisected by intermittent stream, which may limit overall treatment area.
	Total available area for wetland creation	127 acres (84 acres usable for wetland creation)	Dedication of roughly 1/3 of total area to right-of-way, embankments, etc.

- Could wetlands at these locations measurably improve Wilsons Creek water quality?

Preliminary analysis of base flow and storm flow treatment indicate that the wetlands could reduce total phosphorus loads in Wilsons Creek. This would be beneficial for the City from the standpoint of addressing the James River total maximum daily load (TMDL).

- In addition to water quality enhancement, could other benefits arise from wetlands construction?

1. Wetlands would attenuate peak flows and improve channel stability.
2. Habitat would be created for animals such as migratory waterfowl.
3. Aesthetic improvements and recreational facilities may be provided by potentially incorporating walking trails or picnic areas.
4. Educational opportunities would arise for local schools.
5. Sites would contribute to the Wilsons Creek-South Creek Greenways network of trails for biking, walking, running and skating.

- What are some of the key wetland design criteria?

1. Include a forebay for sediment deposition. This feature may extend the life of the wetland by reducing clogging and premature filling.
2. Vary bottom topography to promote heterogeneity of vegetation composition. Include areas of open water and high marsh.
3. Disperse flows to maximize contact time and minimize channelization and short-circuiting.
4. Maintain appropriate hydrology. Adequate long-term water supply must be ensured to establish and maintain a wetland ecosystem. Alternate water sources should be identified for dry seasons. Extended periods of flooding should also be avoided.
5. Design for retention times of less than three days to prevent breeding of nuisance species, such as mosquitoes.

- What are the major design and construction issues associated with wetlands creation? In particular, what are the most significant implementation issues, both technical and non-technical?

  1. Since wetlands have not existed previously at these sites, plants may not readily be available. Research into amenable species is required.
  2. Significant earthwork may be required to improve site suitability for wetland creation.
  3. Public perception of wetlands may be negative, at least in some respects. Since wetlands have not previously existed in these areas, the public may prefer that the parcels remain in an "upland" condition. It is important to address public reaction early, for example, with respect to mosquito breeding. (WWE previously sent you a memo on this subject.)
  4. Permitting issues may arise for both construction and maintenance. It is recommended to consult with the U.S. Army Corps of Engineers (USACE), Missouri Department of Natural Resources (MoDNR), Missouri Department of Conservation (MDC), and the Natural Resources Conservation Service (NRCS) early in the process.

- What costs are anticipated for construction?

  1. WWE's wetland projects have a typical construction cost range of $30,000 to $50,000 per acre, not including land costs. Preliminary estimates may be adjusted for the extent of excavation (anticipated to be high), obtaining plants, environmental audits, and large-scale application. Cost estimates will be refined with design.
  2. Based on the construction estimate, and estimated pollutant removal for the three most upstream sites only, costs are anticipated at approximately $1,000 - $1,800/lb P removed, for a system designed to treat both storm and base flows.

- What capital and operations/maintenance/replacement (O/M/R) tasks should be anticipated (at a conceptual level)?

  1. Several years (3-5) are required for wetland establishment. During this time, frequent inspection and maintenance, particularly for replacement of vegetation, is necessary. WWE experience indicates that annual replacement of 10-20 percent of initial plantings is necessary during establishment. Representative vegetation cost is $1.50 per plant, and density is 4,840 plants per acre. Therefore, revegetation is estimated at $61,000-$122,000 per year, based on 84 acres of vegetated wetland area, as per Table 1.
  2. Monitoring of pollutant removal performance. WWE estimates monitoring costs of approximately $3,300 per site for three storm events per year. This estimate does not include laboratory fees, equipment, coordination, or reporting.
  3. Accumulation of sediments may be substantial. Forebays will require clean out at least once per year.
  4. Periodic vegetation harvesting.
  5. Hydraulic structure maintenance.
  6. Periodic repairs from damage during larger, infrequent floods.
  7. Mosquito control.
  8. Operation and maintenance costs are highly site specific and depend on the adopted design approach. An initial estimate of 2 percent of construction costs suggests long-term O/M/R costs are $76,200-$127,000 per year based on construction of 127 acres (total construction, as per Table 1).

- If the City decides to continue with engineering feasibility analysis, what tasks should be pursued during the next stage of investigation?

  1. Soil borings for depth to bedrock at specific sites, core samples for substrate profile, and assessment of potential fractures or other significant features.

2. Refine hydrologic calculations to include specific site and seasonal investigation. For example, water availability may significantly fluctuate between spring, summer and fall. Preliminary water budgets should be identified to assess potential impacts to the wetland ecosystem.
3. Conceptual site design for identification of inlet solutions, estimation of required excavation and associated costs.
4. Consultation with USACE, MoDNR, MDC, NRCS, and Greene County.
5. Refine pollutant removal calculations for better assessment of impact on receiving water quality.
6. Detailed discussions with local experts on plant selection.

1.0 INTRODUCTION

Wilsons Creek (also known as Wilson's or Wilson Creek) is a major drainageway for the City of Springfield, Missouri, as shown in Figure 1. The City is interested in improving Wilsons Creek water quality by integrating riparian wetland zones. Nationally, constructed wetlands have been successfully implemented for reducing ambient stream and stormwater runoff contaminants. As a result, the City retained Wright Water Engineers, Inc. (WWE) to perform a feasibility study to evaluate the potential benefits to Wilsons Creek water quality.

The City identified five candidate sites for wetland creation, as shown in Figures 2-6. The following report discusses case studies for similar applications, design criteria for constructed wetlands, existing water quality concerns in Wilsons Creek, potential for water quality improvement, long-term maintenance needs, site constraints, and costs. Recommendations are also made regarding site configuration and additional data needs for refined analysis.

2.0 CASE STUDIES

Use of constructed wetlands to treat storm flows has been well documented. However, water quality improvement from treating base flows with constructed systems is less well known. For this reason, two case studies for base flow treatment by constructed wetlands were investigated. In the Denver area, the Shop Creek pond and wetland system was built in an on-line configuration to serve a drainage area of 550 acres, which is comprised mainly of single-family low-density housing and is approximately 40 percent impervious. Data from Shop Creek indicate that treatment of base flows, in addition to storm flows, can significantly decrease the annual pollutant load. An assessment of average seasonal load total suspended solids (TSS) removal indicated 68 percent for the pond-wetland system during the first three years after construction. Pollutant removal resulted in an average TSS outflow concentration of 22-41 mg/L. Considering treatment of base and storm flows for total phosphorus (TP) removal indicated an annual load reduction of 45 percent. Monitoring of the pond-wetland system was revisited several years later to assess performance with respect to age and establishment of the wetland. Pollutant removal increased to 91 percent for TSS and 71 percent for TP for the combined system.

The Des Plains River Wetlands Project (Illinois) was initiated to help restore a mid-western river system with substantial water quality problems. Four wetland cells were constructed in an agricultural (80 percent) and urban (20 percent) watershed. Constructed cells ranged from 4.4 to 8.6 acres and had a maximum water depth of approximately 5 ft. The system served a drainage area of 146 mi^2. Through controlled cyclic pumping, between 20 and 40 percent of the river flow was diverted through the series of constructed wetlands. Hydraulic loading rates[2] ranged approximately 0.03-0.30 ft/day, and retention times ranged from approximately one to three weeks. Annual mass balance analysis for each cell (based on two years of data) showed 76-99 percent removal of TSS, 52-99 percent removal of TP, and 39-99 percent removal of nitrates, but also showed seasonal variation. The effluent quality was determined to be generally the same, regardless of loading rate. Researchers suggested that the consistently high performance of the

[2] Hydraulic loading rate (HLR) is a common design parameter for treatment systems. It is defined as the ratio of flow rate in volume/time (i.e., ft^3/day) to surface area of the treatment system in length squared (i.e., ft^2). Conceptually, the HLR is a depth of water resulting from spreading the total volume evenly over the treatment area for a specified period of time.

wetlands indicated an ability to effectively treat flows at higher loading rates. Modeling of pollutant retention indicated TP retention of 4.5–26.8 lb P/acre-year. Sediment deposition ranged from approximately 6,245-29,400 lbs/acre-day for low and high loading rates, respectively. As expected, water velocity had the most effect on sedimentation rate. In the low loading basins, effects of vegetation were significant. Increased vegetation density decreased flow rates, hence enhancing sedimentation, contact time, and pollutant uptake.

The analysis was not extended to effects on the receiving water; however, the high removal rates in the cells combined with the magnitude of diverted flows implies improvement to the Des Plains River.

3.0 LOCAL DATA SOURCES

Flow and limited water quality data are available from the USGS for three stations along Wilsons Creek:

1. USGS 07052000 Wilsons Creek at Scenic Drive (farthest upstream).
2. USGS 07052100 Wilsons Creek near Springfield.
3. USGS 07052160 Wilsons Creek near Battlefield (farthest downstream).

Based on locations of the gauges with respect to candidate wetland sites, and other data available at this time, the majority of the following analysis focuses on treatment only at the three sites upstream of the Springfield gauge. All USGS water quality samples were collected prior to implementation of the recent phosphorus controls at the SWTP. Comparison of pre- and post-SWTP phosphorus removal data (see discussion in Section 4.0) shows substantial reductions in instream phosphorus. Therefore, the USGS data are not considered in the present analysis.

Additional water quality data were obtained from the Department of Public Works (DPW) that manages the SWTP. The City provided mapping of the floodplain, rough estimates of site location, utilities, soil surveys, and detailed topography of individual sites. Also provided was the Soil Survey of Greene and Lawrence Counties, Missouri, prepared by the U.S. Department of

Agriculture Soil Conservation Service. The James River Watershed TMDL report was downloaded from the MoDNR website.

4.0 WILSONS CREEK WATER QUALITY

Wilsons Creek is a sub-watershed of the James River Watershed. Segments of both rivers are on the proposed MoDNR 303(d) list of impaired waters. According to the proposed list, 59 miles of the James River are impaired by nutrients and "unknown" pollutants from urban non-point runoff, and 14 miles of Wilsons Creek are impaired for unknown toxicity from unknown sources. A James River TMDL for nutrients was approved by the U.S. Environmental Protection Agency (USEPA) in May 2001. The City of Springfield is the largest urban area within the watershed. Significant growth has also been observed recently in the communities of Ozark and Nixa in Christian County.

The James River TMDL specifically targets reductions in Wilsons Creek pollutant load, since it is considered a major tributary to the impaired segments. The report indicates that James River TP levels significantly increase below the confluence with Wilsons Creek. The TMDL allocation for Wilsons Creek reduces loads of 116,206 lb P/year to 5,810 lb P/year. The TMDL report suggests that this goal may never be achieved given existing amounts of nutrients in Wilsons Creek. Phase I of TMDL implementation targets TP reductions generally from point sources and urban stormwater runoff and is focused on Wilsons Creek.

It is important to note that the TMDL was completed prior to implementation of phosphorus controls at the SWTP in January 2001. Table 2 shows a significant decrease in Wilsons Creek TP concentration downstream of the SWTP after January 2001, based on data collected at several sampling stations. On an average annual basis, implementation of TP controls at the plant has reduced the concentration in Wilsons Creek by approximately 87 percent. WWE believes that the 116,206 lb P/year TMDL estimate is therefore no longer valid as a basis for comparison of the potential effects on Wilsons Creek water quality through implementation of treatment wetlands. Estimation of potential impacts is therefore evaluated in this report in terms of percent treatment of storm and base flow loads. This is discussed in detail in Section 6.7.

Table 2. Total Phosphorus Concentration in Wilsons Creek in Stations Below the Southwest Treatment Plant*.

Wilsons Creek Sampling Station	Average TP Concentration (mg/L) 1992 – 2000	2001 – 2002
Second Bridge in National Park	1.90	0.28
Manley Ford	2.03	0.29
North Edge of National Park	3.50	0.38
Below SWTP	2.00	0.31
Average	2.35	0.31

*Based on data collected by DPW.

Nitrogen loadings are also discussed in the TMDL. A target James River in-stream total nitrogen (TN) concentration was determined, but a detailed waste load allocation was not. The TMDL targets Wilsons Creek TN load reduction from 786,819 lbs/year to 116,206 lbs/year. However, improvements to James River water quality are focused on reduction in TP loads. Results of monitoring from the Phase I TMDL implementation will be used to refine TN allocations for Phase II.

5.0 STORMWATER WETLAND DESIGN CONCEPT

Constructed wetlands for stormwater treatment include several design features to promote water quality enhancement. Research in the literature, as well as practical experience of WWE, indicates that in general, stormwater wetlands should be built in an off-line configuration similar to the plan and profile presented in Figure 7. An inflow mechanism accommodates flows of specified magnitudes, but provides energy dissipation to decrease velocities, increase sedimentation, and minimize flush-out of accumulated material during extreme events.

Before entering the wetland zone, inflow is directed to a forebay to reduce sediment loadings to the wetland, and hence prolong the life of the system. According to the Denver Urban Drainage and Flood Control District (UDFCD) design criteria, the sediment forebay should occupy approximately 10 percent of the water quality capture volume. This guideline is consistent with other recommendations found in the literature. Forebays should be concrete-lined and have direct access for maintenance equipment. The forebay should be separated from the wetland area by a low berm which disperses flow evenly. Inflow and forebay configuration and location should prevent short-circuiting of the system.

The wetland flow path should prevent channelization or stagnation. The general shape should gradually expand from the inlet and contract toward the outlet, and have a length to width ratio of 3:1 whenever possible. Maximum side slopes should be maintained at 4:1. Longitudinal slope should be restricted to less than 1 percent (UDFCD, 1999; Mitsch and Gosselink, 1993).

In general, success of treatment wetlands in creating habitats and improving pollutant removal is increased by encouraging heterogeneity of wetland composition. WWE's experience strongly supports this. For example, site design guidelines include varying bottom topography (and hence permanent pool depth) to create zones amenable to all types of wetland vegetation. UDFCD recommends that the forebay, outlet, and free water surface should occupy 30-50 percent of the permanent pool surface area at a depth of 2-4 ft. Wetland zones with emergent vegetation should occupy 50-70 percent of the permanent pool volume surface area at a depth of 0.5-1.0 ft (UDFCD, 1999). Recommendations from the state of Maryland suggest water depths of 0.5 ft for 50 percent of the wetland area, and the remainder split evenly between 0.7 ft and 2-3.3 ft. However, during establishment, water levels should generally be kept lower to allow emergent vegetation to secure a root system. Florida guidelines recommend that open water areas comprise less than 70 percent of the total site (Mitsch and Gosselink, 1993). WWE's experience suggests that for base flow systems, inundation of shallow areas should be restricted to 0.5 to 1.0 ft. For storm flow treatment systems, inundation can be increased to a maximum of 2 ft for a duration of two days.

Inundation depth is maintained by structural outlet works. Outlet works should be at the farthest point from the inlet. Both inlet and outlet configuration should avoid clogging from sediments or other debris and be protected by a trash rack. Public safety must be accounted for with trash rack design, as well.

Other desirable features include an emergency spillway, as well as an inlet limitation structure for high-flow events, provisions for eventual system drainage for long-term maintenance, and areas for on-site disposal of dredged material (from frequent forebay cleaning). All berms should have at least a 12 ft width at the top to allow for maintenance vehicles. MoDNR regulations will be consulted for any other specific requirements for treatment wetlands creation in further study.

Design of candidate sites for Wilsons Creek wetlands are addressed in more detail in the following text.

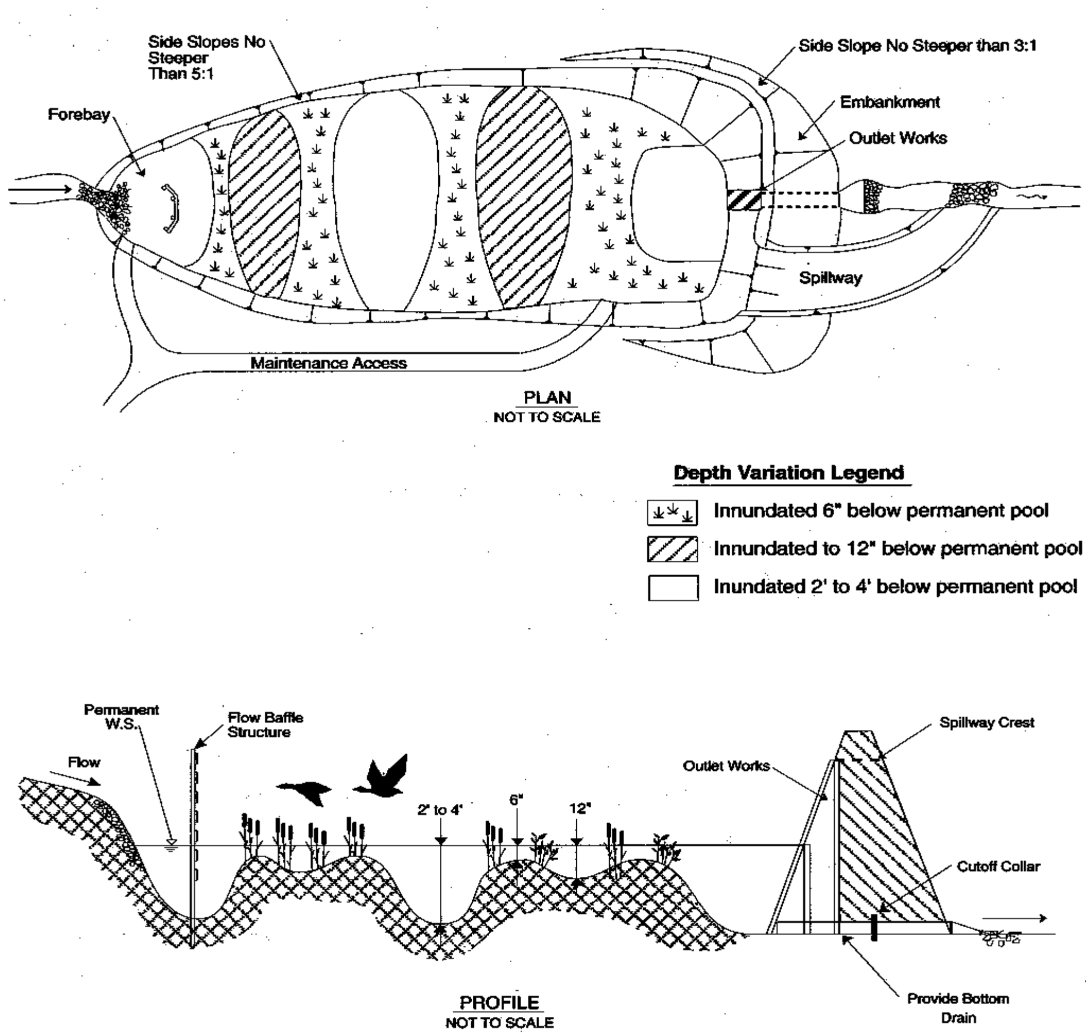

Figure 7

Conceptual Constructed Wetland Plan and Profile

Source: Denver Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual, Volume III* (1989).

6.0 FEASIBILITY ISSUES

6.1 Identification of Goals

The goals of the wetlands creation project need to be carefully specified. According to Bavor et al. (1995), in wastewater treatment wetlands, the area of wetland required varies depending on the type and extent of pollutant removal. Poor performances reported in the literature can often be attributed to improper design for specified goals. Therefore, representative important questions to address in the immediate future include:

- Are the wetlands to be used for base flow treatment and/or stormwater (high flow) treatment?
- If wetlands are specified for stormwater treatment, what storm magnitude should be treated?
- Should detention or peak attenuation of storm flows be addressed in addition to water quality function?
- In light of the TMDL for the James River discussed above, is phosphorus and/or nitrogen removal the primary goal of wetland creation?
- With the potential treatment area available, will there be a measurable improvement in Wilsons Creek water quality for phosphorus and/or nitrogen?
- What other multi-purpose goals should be targeted?

6.2 Floodplain Impacts

All of the potential wetland sites are located (at least partially) within the 100-year floodplain. Any changes to the floodplain should be considered in more detail. For example, what are the effects of storing flood waters at Site 4 since it is in close proximity to the SWTP? Modification of the floodplain may involve an official update of the Flood Insurance Rate Map (FIRM) through the LOMR (Letter of Map Revision) process, which can be time consuming and expensive. The City would need to interact with Greene County on any floodplain issues. Discussions with County staff are recommended.

Effects of frequent flooding on treatment wetland sites should also be considered. Although typical wetland vegetative species are generally adapted to extended periods of inundation, the flood tolerance of plants cannot be exceeded, as this would reduce productivity, or perhaps cause die-off of some plant species. Furthermore, pollutant accumulation during "regular" flow periods, or up to a specified design flow, may be substantial; however, if appropriate hydraulic controls are not included, increased flow velocity during larger flood events may flush out settled, accumulated materials. A design goal should be set, and hydraulic controls investigated to evaluate potential long-term performance.

6.3 Soil/Geology Concerns

Maintaining proper hydrology is crucial to creation and survival of a wetland ecosystem; inattention to site hydrology is the primary cause of wetland failure nationally. The Springfield region is generally characterized by karst geology with bedrock often near the surface separating surficial soils from the shallow groundwater system. This creates the potential for significant infiltration losses, and hence mandates detailed field testing of candidate sites. If shallow bedrock is present, the sites would require lining, probably with on-site clay. Shallow bedrock could necessitate blasting, and hence increased cost. It is likely that topsoil will have to be imported to create suitable conditions for plant growth.

The <u>Soil Survey of Greene and Lawrence Counties, Missouri,</u> in which most of the study area is mapped on Sheet 58, was investigated for local conditions. Four soil mapping units dominate the floodplain in the area(s) under consideration for wetland creation. Each of these soil types is discussed below. In general, soils are mixtures of clay and loam with the depth to bedrock greater than 60 inches. Loam and sandy-loam soils are preferable for growth of wetland vegetation (Mitsch and Gosselink, 1993), but soil survey data indicate that occasional to frequent flooding of the soil types present would have a good potential to maintain the saturated conditions required for wetland establishment. Discussions with City and County representatives indicate that it is likely that on-site soils with appropriate preparation and compaction during construction could serve as suitable liner material.

If unsuitable conditions are determined (from a soil or geology standpoint) for some sites, it would be necessary to evaluate whether the reduced area would still be adequate to achieve water quality goals. Candidate sites need to be addressed individually in further study. Soil borings for depth to bedrock at specific sites, core samples for substrate profile, and identification of possible fractures are important data to collect. Available information for on-site soils follows (these are taken directly from the County Soil Survey):

- Type 44E: Goss-Gasconade Complex

  1. Extent of Goss versus Gasconade varies, but averages 60 percent Goss, 40 percent Gasconade.
  2. Goss: cherty silt loam about 4 inches thick. Subsoil to about 60 inches is firm cherty silty clay loam in upper part, very firm cherty silty clay in middle, and very firm cherty clay in lower part.
  3. Gasconade: stony silty clay loam about 11 inches thick. Hard limestone bedrock is at a depth of 11 inches.
  4. Water capacity is low in both soils, and could limit use.
  5. Gently to steeply sloped – can be limiting for pond/reservoir areas.
  6. Depth to bedrock >60 inches.

- Type 54: Lanton Silt Loam

  1. Deep, nearly level, somewhat poorly drained soil.
  2. Frequent flooding.

3. Surface soil is about 29 inches thick, Silt loam in upper, silty clay loam in middle, mottled silty clay loam in lower. Substratum to about 63 inches mottled firm silty clay loam in upper part, strong silty clay loam in lower. Lower part is also gravelly in places.
4. High available water capacity. Moderately slow permeability. Water table at about 1-2 ft December to May. Very wet soils.
5. Depth to bedrock >60 inches.

- Type 55: Huntington Silt Loam

1. Deep, nearly level, well drained soil.
2. Surface soil is about 12 inches thick (but can be <10 inches or >24 inches). Subsoil is friable silt loam about 36 inches thick. Substratum to 60 inches mottled silt loam. Lower substratum is gravelly.
3. Moderately permeable, high available water capacity. Water table at 4-6 ft December-April. Occasional flooding. Moderate seepage can be expected (possibly good for removal of dissolved P).
4. Depth to bedrock >60 inches.

- Type 95: Cedargap Silt Loam

1. Deep, nearly level, well-drained soil.
2. Frequent flooding.
3. Surface soil about 20 inches thick silt loam. Substratum to depth of 72 inches very cherty silty clay loam in upper, very cherty silt clay in lower. Surface can also be cherty.
4. Permeability is moderately rapid, moderate available water capacity. Severe seepage for pond/reservoir areas.
5. Depth to bedrock >60 inches.

6.4 Hydrology

Since water availability is the most critical factor in maintaining a wetland habitat, a key initial step in designing treatment wetlands is to identify a preliminary hydrologic "budget." A hydrologic budget is a mass balance of water inputs, withdrawals and changes in storage within a system. Designing a suitable hydrologic budget for any given wetland includes consideration of flood tolerance of a wetland ecosystem, impacts of pollutant loads associated with inflows (i.e. toxicity, low dissolved oxygen), and impacts to the receiving water. Another important factor is the effect of high temperatures, which may increase evapotranspiration, thereby decreasing the amount of available water and potentially increasing pollutant concentrations, such as total dissolved solids (TDS). This effect may be seen in both the wetlands and in Wilsons Creek.

Wilsons Creek is periodically subject to large, "flashy" flows, especially in the vicinity of Site 1 (near the old trailer park) as well as periods of zero flow (per interview with Todd Wagner, P.E.). Results of a preliminary analysis of daily stream flow at the USGS Springfield gauge on Wilsons Creek for the period 1973-1982 are presented in Table 3. Based on rough approximation of three potential sites (Sites 1, 2, and 3), approximately 53 acres of wetland treatment area could potentially be established upstream of this gauge. Much of the analysis presented in the remainder of this report relates specifically to the three upstream wetlands, and to the flow data in Table 3.

Table 3. Preliminary Investigation of Hydrology at Springfield Gauge*.

Month	Average Daily Flow (cfs)	Average Storm Flow (cfs)	Average Storm Duration (days)	Average Number of Storms (per month)
January	12.6	85	1.3	1.6
February	15.6	57	2.5	1.5
March	35.6	124	3.0	1.8
April	31.8	115	2.4	2.0
May	34.2	118	1.8	1.7
June	29.3	129	1.9	1.7
July	18.5	124	1.5	1.4
August	9.5	67	1.4	1.5
September	13.9	127	1.6	1.5
October	16.6	93	1.4	1.2
November	24.4	162	2.4	1.3
December	14.3	68	1.8	1.3
Annual Average	21	106	1.9	1.6

*Basis: Daily stream flow records from USGS 07052100 Wilsons Creek near Springfield. Storm flows were identified as increases in river flow greater than 15 cfs. Calculations should be refined in future studies for establishing specific return frequencies for given magnitudes.

The data in Table 3 are useful, but more refined hydrologic analysis is imperative if the City continues feasibility studies. The appropriate next steps in the Wilsons Creek hydrologic analysis are to refine storm flow magnitude estimates to include downstream data as well as to determine return frequencies of storm events. River stage associated with average daily and storm flows must also be determined to help define individual site hydrologic budgets. Return frequency estimates are necessary to determine what magnitude and frequency of storm event can be accommodated without adverse effects to the wetland, as discussed above, and likewise what types of hydraulic controls may be required.

6.5 Site Design and Availability

In the current application, an overriding question with regard to site availability is whether sufficient area exists to have an impact on water quality in Wilsons Creek. The total estimated usable area for wetland creation is 84-85 acres (for all five sites, combined), if one third of each site is dedicated to berms, easement, and/or right-of way, etc. Rough (initial) wetland boundaries are outlined in Figures 2-6, based on constraints from physical features identified in aerial photography and topography maps provided by the City. Please note that WWE has only conducted a "windshield survey" of the sites, to date, so the delineation in Figures 2-6 may change substantially with detailed site evaluation. Each site has unique conditions which may limit or dictate wetland shape, and are discussed individually below.

At almost all sites, steep riverbanks could create issues for inlet diversion. Several options exist to address inlet configuration. Mechanical pumping of inflows is not considered. At this point, options have been addressed qualitatively and all warrant further investigation.

- Upstream gravity diversion. Inlet works and a pipeline (or open channel) would have to be installed. Site details and upstream conditions (slopes, presence of utilities, location of inlet diversion) need to be investigated in further detail for estimation of cost and feasibility. Right-of-way could be a concern.
- Check dams combined with side channel weirs, could be installed in Wilsons Creek to increase the depth of flow. This option would result in permitting issues (for example, flood plain impacts) and potentially channel morphology changes.
- Installation of side channel weirs at base flow elevation, combined with excavation of the wetland site to establish an elevation lower than the weir elevation. Site photos indicate that this method may be favorable (compared to the above options). Extent of required excavation, and hence associated cost, is yet to be determined. This option would be appropriate for treatment of above-average flows only.

An important data need relative to these three diversion options is stage-discharge-frequency relationships for Wilsons Creek at each candidate site. WWE currently lacks data of this kind.

Several other site characteristics require consideration for project feasibility. Off-line configuration limits actual treatment area when berms and right-of-way are incorporated; however, berms or formal outlet structures may not be necessary along all borders or to separate the forebay from the wetland area due to natural steep topography. On the other hand, steeper banks may require significant regrading of sites to facilitate flows parallel to the river, and hence avoid the need for pumping and complicated routing. This may encroach further upon usable treatment area.

At Sites #2 (Figure 3) and #5 (Figure 6), the presence of small tributary streams may limit treatment area. Further investigation is required to determine characteristics of these tributary streams. For example, if stream flows are small, discharges may be made directly into the wetland, rather than into Wilsons Creek. A second option would be to re-route streams to discharge downstream of the wetland area(s). If neither of these options is feasible due to regulatory, permitting, public objections, or other factors, then treatment sites are significantly limited in extent of usable area. The overall analysis should be refined to account for these limitations.

Existing roads form many of the borders along the width of wetland sites. However, the length of sites may extend along unimproved areas, which may create the need for building access roads. Furthermore, access to the sediment forebay is crucial for frequent maintenance and appears to be difficult in many of the potential sites. Overall, maintenance access is quite limited.

Preliminary sketches should be refined to determine the extent of earthwork, and hence construction cost, which may be required. Furthermore, the hydrologic analysis and estimate of potential annual pollutant load reduction did not include treatment or routing of overland flows, and should be done in future analysis.

Preliminary rankings are provided. Rankings were qualitatively determined considering proximity to pollutant sources, impacts to surrounding property, and ease of construction. These rankings should be considered preliminary and qualitative only at this time. Rankings should be refined based on quantitative analysis of individual site performance and construction cost.

6.5.1 *Site #1*

- **Location**: West border is an unnamed road (on available maps), east border is Scenic Ave. Wetland creation to north of river, possibly including forested area. In close proximity to highly developed urban area. Refer to Figure 2.
- **Total Estimated Area for Wetlands Creation**: approximately 31.5 acres (21 acres usable).
- **Concerns**: Site slope parallel to the river is somewhat steep. Significant regrading of site may be necessary. Rough delineation and estimation of cut and fill material if the entire site is used indicates that significant fill may be generated at this site, and hence potentially increase overall cost due to disposal. Key feasibility questions include: if the site is restricted to avoid excess material generation, what is the remaining extent of treatment area? How might the restriction impact the expected annual pollutant load reduction?
- **Rank**: 3

6.5.2 *Site #2*

- **Location**: North border approximately 0.4 miles north of Bennett St. (Farm Rd 146); south border is Bennett St. The City is currently acquiring property including this parcel that is dedicated for parks and open space use. Refer to Figure 3.
- **Total Estimated Area for Wetlands Creation**: approximately 37.3 acres (25 acres usable).
- **Concerns**: While Site #2 is relatively flat, bottom slopes of approximately 0.25 and 0.67 percent exist sloping towards the center where a small tributary stream segments potential wetland area. The creation of two wetland cells at this site (divided by the stream) will likely not be necessary to accommodate tributary flows, although characteristics of this channel should be investigated. Difficulties may also be encountered in providing maintenance access for the entire site. For example, the upstream end of the site (where the forebay would be located) is not near currently

constructed roads. The eastern extent of the site is limited by steep slopes, thereby causing encroachment into potential treatment area to build access. Relying upon the river (west) side for maintenance access may pose a risk during high flow events – or for subsequent maintenance after extreme events.

- **Other**: Construction could be coordinated with Springfield-Greene County Parks Board and Ozark Greenways.
- **Rank**: 1

6.5.3 *Site #3*

- **Location**: North border is F.R. 156; south border is James River Freeway. Refer to Figure 4.
- **Total Estimated Area for Wetlands Creation**: approximately 11.2 acres (7 acres usable).
- **Concerns**: Site #3 is bisected by Wilsons Creek. Areas exist for wetland creation along both banks of the river; however, the site is broken into three parcels, which may result in increased construction costs. The north wetland would most likely not require substantial regrading; however, overland flow may be an issue due to steep topography at the edge of the flood plain. The north end of the site provides easy access to a forebay from Farm Road 156, and access may potentially extend approximately half the length of the site without significant earthwork.
- **Rank**: 4

6.5.4 *Site #4*

- **Location**: Bounded by James River Freeway on the north and the north end of the SWTP to the south. Wetland creation area on southwest side of river (refer to Figure 5).
- **Total Estimated Area for Wetlands Creation**: approximately 28 acres (19 acres usable).

- **Concerns**: The most significant concern at Site #4 is the close proximity to the SWTP. Effects of altering the floodplain in this area must be investigated in more detail. Other issues arise from the presence of steep banks which may require significant regrading to facilitate flows parallel to the river. The southern portion of the site slopes towards the river at approximately 2.8 percent, while the slope along the length of the river is approximately 0.68 percent. Consideration must be given to creating a flow path parallel to the river. Similar to Site #2, creation of maintenance access is hindered by the meander of the river and steep slopes at the edge of the flood plain.
- **Rank**: 5

6.5.5 *Site #5*

- **Location**: North border is Farm Road 168; south border is Highway M. Refer to Figure 6.
- **Total Estimated Area for Wetlands Creation**: approximately 18.6 acres (12 acres usable).
- **Concerns**: Wilsons Creek divides Site #5, and hence the site may potentially be comprised of two wetlands, along each bank of the river. One cell is bordered on the west by steep slopes, on the east and north by Wilsons Creek, and by Highway M on the south. The west border shows steep topography. While this may eliminate the need for a berm on this side, relying upon the river (east) side for maintenance access may pose a risk during high flow events – or for subsequent maintenance after extreme events (i.e., if the berm was washed away during a 500-year event). The proposed location of the forebay may also prohibit access. A similar situation occurs for the other wetland area at Site #5 with respect to the berm; however, the close proximity of the proposed inlet location is acceptable for access to a forebay.

  Creation of an eastern wetland at Site #5 may require significant regrading. The site slopes towards the river at approximately 2.6 percent, while the slope along the length of the river is approximately 0.4 percent. Consideration must be given to creating a flow path parallel to the river.

Potential wetland areas are further limited by the presence of small tributary streams, as in the case of Site #2. Likewise, the same options and issues exist for routing of tributary flows as at Site #2.

Other: Site 5 is the most downstream location and is the only area which might receive effluent from the SWTP.

Rank: 2

6.6 Sizing Methodologies

Several methods exist for sizing of treatment wetlands. Each method is investigated below. WWE has assumed that the sites will be constructed in an off-line configuration.

6.6.1 Hydraulic Loading Rates

Since sedimentation is the primary mechanism for TP removal and site hydrology is critical for wetland establishment, defining sustainable loading rates is essential to effective design. Hydraulic loading rates (HLRs) address some of these issues for sizing considerations.[3] Guidelines in the literature and WWE's practical experience indicate that an appropriate storage volume for a base flow system is 0.5-1 ft, with a retention time of one day. It is unreasonable to design systems such that the total Wilsons Creek base flow would be diverted through the wetlands due to riparian and aquatic habitat impacts, among other reasons. Therefore, it is assumed that approximately 25 percent of the base flow volume could be diverted while 75 percent remains untreated by the wetlands. WWE also recommends that the wetlands treat high flow (storm) discharges, subject to an average inundation depth of 2 ft (total) for a duration of two days. Wetlands can tolerate more significant flooding for a limited, shorter duration as

[3] Hydraulic loading rate (HLR) is a common design parameter for treatment systems. It is defined as the ratio of flow rate in volume/time (i.e., ft^3/day) to surface area of the treatment system in length squared (i.e., ft^2).

compared to the "average" condition. Specifics of site design are addressed in more detail in subsequent sections.

The HLRs determined according to the preceding assumptions are presented in Table 4. Back-calculation yields estimates of the fraction of total flows that may be routed through the wetlands, within the tolerance of the treatment systems. These capacities were then compared to actual flow data collected in Wilsons Creek to determine the "allowable" design HLRs.

As discussed earlier, flow data were obtained from the USGS for gauges in Wilsons Creek at Scenic, at Springfield, and near Battlefield. Inspection of the data indicates that stream flow is similar at the Scenic and Springfield gauges; however, flow substantially increases at the most downstream gauge at Battlefield due to discharges of several tributaries and of two treatment plants. At this stage, storm flows were only identified for the Springfield gauge, as described in Table 3, and therefore provides the basis for the current analysis.

Table 4. Hydraulic Loading Rates for Potential Wetland Sites 1-3.

Available Treatment Area (acres)	HLR Capacity of Wetland Sites (ft/day)		Percent Annual Flow Diverted		Design HLR (ft/day)	
	Base	Storm	Base	Storm	Base	Storm
53 (upstream of Springfield Gauge; sites 1-3)	0.5-1.0	2	25	50	0.33	2

If the City continues feasibility studies, the calculations presented in Table 4 should be expanded to include the two downstream treatment sites. Flows change substantially between Springfield and Battlefield; therefore, the design HLRs for the downstream sites (Sites 4 and 5) may be significantly different than for Sites 1-3.

As discussed above, researchers in the Des Plains River Wetlands Project observed good performance for base flow HLRs of 0.03-0.3 ft/day with extended residence times. Mitsch and

Conceptually, the HLR is a depth of water resulting from spreading the total volume evenly over the treatment area for a specified period of time.

Gosselink (1993) report an average HLR for surface flow wastewater treatment wetlands of 0.2 ft/day ± 0.06 with a range of 0.05-0.7 ft/day. Further investigation of combined effects of probable HLR with associated pollutant loads is warranted since preliminary investigation indicates the potential for substantial water quality improvement in the treated flow.

6.6.2 Area Loading Rates

Since hydrology is a crucial element for wetland survival, area loading rates (ALRs) were estimated according to the HLRs discussed in the previous section. ALR is similar conceptually to HLR. ALR is defined as the mass of pollutant per unit area of treatment system. ALR has been used to define tolerances for wetland pollutant assimilation as well as applied to cost-benefit analysis.

Water quality data provided by the DPW were collected at five sites in Wilsons Creek several times each year from 1992 to the present, although not all parameters of interest have been monitored, nor have wet weather samples been collected. For base flow water quality, only data for the sampling station upstream of the SWTP were used. Concentration values reported at less than method detection limits were not included at this stage of the analysis; therefore, ALRs presented in Table 5 are conservative estimates for a range of water quality and flow rates. The base flow TP concentration was estimated at 0.1 mg/L, while storm flow concentrations were assumed to be 0.5 mg/L. (TP refers to total phosphorus in the text below.)

Table 5. TP Area Loading Rates For Three Upstream Wetland Creation Sites.

	Treated Annual Average Base Flow	Treated Annual Average Storm Flow*
Wetland Design Flow	5.5 cfs/day	53 cfs/day
Total Phosphorus (TP) ALR	0.1 lb/acre-day	1.7 lb/acre-day

*During storm events only.

Studies of constructed wetlands used for wastewater treatment have reported reduction of inflow TP concentrations from 1-2 mg/L to 0.005-0.30 mg/L with an ALR of 0.07-0.10 lb/acre-day. Similarly, sustained 60 percent reduction of TP loads were observed in a system receiving 0.07-0.12 lb/acre-day (Bavor et al, 1995). Phosphorus retention in constructed wetlands was generally observed to decrease with increased annual loading rates, but will also depend on other site characteristics, such as soil chemical characteristics (Mitsch and Gosselink, 1993). Combining all data points for the monitoring stations, average TP concentrations for Wilsons Creek ranged from non-detects upstream of the SWTP to 0.14–0.51 mg/L downstream. In the current application, loading rates are estimated at 0.1 lb/acre-day for base flow treatment for the upstream sites, and 1.7 lb/acre-day for storm flow treatment.

Based on the guidelines and estimates presented in Table 5, candidate sites should be able to treat 25 percent of the base flow with measurable improvement. Literature values for storm treatment system ALRs were not readily available at this time; however, based on other performance data, it is reasonable to assume that the significant loading rate as predicted by the ALR for a short duration, such as that of a storm event, will not overload the system. Further refinements to calculations are warranted, especially to determine loading rates for downstream sites. (These calculations were not performed at this time due to the need for further analysis of the flow regime). Impacts to receiving water quality on an annual basis are discussed in more detail below.

With respect to sedimentation, wetlands should be sized such that the annual loading is limited to 0.5-1 inch of accumulation. For example, for a base flow treatment system, if the average TSS loading is 50 mg/L, and treated flow is 5.5 cfs/day, 1,485 lbs of sediment enters the wetlands each day. If all of the loading was removed, assuming a density of 85 lbs/ft^3, approximately 6,377 ft^3/year of sediment, or 1.76 acre-inches/year would accumulate. This initial assessment assumes treatment of a quarter of the base flow and 100 percent removal of pollutant without a forebay. Obviously, these conditions would not be expected, but even removal of 50 percent of the load could result in substantial accumulation. Loadings from storm events are likely to be even more substantial. For this reason, inclusion of a sediment forebay is important in design. Furthermore, maintenance of the forebay is likely to be necessary roughly once per year.

6.6.3 Residence Times

The 1999 Denver *Urban Storm Drainage Criteria Manual (Volume III)* recommends a 12-hr residence time for (wet) retention ponds and a 24-hr residence time for effective treatment of the water quality capture volume by constructed wetlands. This range is appropriate for the Wilsons Creek wetlands. Studies have suggested that extended residence times in wetlands may also increase water temperature, and possibly favor conditions which promote algal blooms. Likewise, providing residence time greater than 72 hrs may enhance conditions suitable for mosquito breeding.

6.6.4 Other Methods

Another "rule of thumb" sizing method is based on watershed size. Guidance from the Denver UDFCD suggests that the wetland should be about 0.5-2 percent of the watershed area. In the current application, the potential contributing drainage area is 35.3-58.3 mi^2. The potential treatment wetland creation area is approximately 84 acres. The ratio of wetland to watershed size is therefore approximately 0.3 percent. This is below recommendations; however, Strecker's (1995) review of available literature concludes that the ratio may not be a significant factor in treatment performance for constructed systems, if the system is designed properly for specific treatment goals. Furthermore, Strecker's regression of the ratio to pollutant removal performance did not yield good direct relationships.

Since hydrology has the most significant effect on wetland creation and survival, hydraulic loadings are considered crucial to wetland design. As assumptions for determining ALRs were consistent with hydraulic loading calculations, it appears that recommended criteria for both methods can be satisfied in the upstream wetland sites. Although ALRs for storm conditions are higher than guidelines for wastewater treatment, WWE's experience indicates that stormwater wetlands should successfully accommodate the loads calculated herein. Design criteria may also be refined to meet specific goals of the James River TMDL for phosphorus, and/or other impending numeric limits, such as for nitrogen.

6.7 Expected Pollutant Removal

In order to assess the potential improvement to Wilsons Creek water quality, an assessment of potential annual pollutant loading reduction was performed for the three scenarios and relative to the three most upstream sites:

1. Treatment of base flows only.
2. Treatment of storm flows only.
3. Treatment of base and storm flows in a combined system.

A preliminary evaluation of Wilsons Creek water quality improvement at the Springfield gauge was performed, which assumes that only Sites 1, 2 and 3 are available for treatment (total 53 acres usable wetland treatment area).[4]

6.7.1 Storm Flow Treatment Assumptions

For the current analysis, WWE assumed a stormflow TP concentration of 0.5 mg P/L.

Several sources claim pollutant removal in stormwater treatment wetlands for TP between 40 percent and 60 percent, but performance may vary substantially according to site and storm characteristics. Seasonality is also important. WWE has assumed that it will be feasible to operate the Wilsons Creek wetlands during the winter (non-wetlands growing season).

[4] Analysis is limited to the three most upstream sites due to current data availability. Assessments will be extended to other sites as data becomes available.

Daily stream flow records were investigated to determine an approximate storm flow magnitude and duration, as described in Table 3. Storms were defined as events which raised flow in Wilsons Creek by at least 15 cfs. These events occurred 1.6 times per month for an average duration of two days on an annual basis. (These assumptions should be refined in future analysis for a better assessment of storm loadings.)

6.7.2 Base Flow Treatment Assumptions

Based on data collected by the DPW, base flow TP concentration was assumed to be 0.1 mg P/L.

More consistent pollutant removal is likely during base flow treatment, as base flow systems function more similarly to polishing ponds in wastewater treatment. However, treatment may be at a lower rate (20 percent) compared to stormwater systems, but this does not necessarily mean effluent concentration will not be as "clean." Actual removal depends on the distribution of pollutant forms and influent concentrations. Since the primary mechanism of TP removal in wetlands is via sedimentation, significant decreases in TP concentrations are realized if most of the pollutant is in particulate form.

Average daily flow for the Springfield gauge was previously described in Table 3.

6.7.3 Annual Pollutant Removal

Table 6 presents results in terms of net pollutant reduction in Wilsons Creek (i.e., combining treated and untreated portions of the flow). It is important to note that the reduction in annual load does not correspond to loadings stated in the James River TMDL. As stated in Section 4.0 of this report, loadings in the TMDL were assessed prior to implementation of phosphorus controls at the SWTP. The SWTP has enjoyed substantial success in reducing TP effluent loads; therefore, the total load in the TMDL is no longer a valid basis for comparison of annual loading rates. As with all other calculations presented in this report, estimation of annual load should be considered preliminary.

Under these conditions, approximately 2,070 lbs P/year should be removed during storms, which correspond to a 20 percent reduction of the annual storm load. Potential accumulation calculated for Wilsons Creek storm loads are higher than reported in the Des Plains River case study; however, researchers indicated that the system was most likely able to handle increased loadings without reduction in performance.

For base flow treatment, approximately 190 lbs P/year would be removed, which is approximately 5 percent of the total annual Wilsons Creek base flow load. Base flow accumulation is consistent with results of the Des Plains River study.

For maximum benefits to Wilsons Creek water quality, the feasibility of a combination (storm and base flow) treatment system should be further investigated. The potential pollutant removal of combined systems designed to treat base flows and storm flows was assessed using weighted averages of base flow and storm flow performance. For this combination system, the reduction in total annual load in Wilsons Creek from treatment at the three upstream sites is approximately 16 percent or 2,200 lbs P/year. Annual load reduction considers both treated and untreated portions of flow.

Table 6. Preliminary Estimate of TP Load Reductions in Wilsons Creek at Springfield by Treatment Wetlands (Sites 1-3 only).

Scenario	Inflow Concentration[1] (mg/L)	% Annual Flow Volume Treated	Assumed % TP Removal	TP Load Removed (lbs/acre)	% Reduction of Annual Load[3]
Storm Flow Treatment	0.5	50[2]	40	39	20
Base Flow Treatment	0.1	25	20	4	5
Combined Treatment		23		42	16

1. Assumed for storm flow. Base flow concentration based on DPW data for the sampling station above the SWTP.
2. Based on allowable 2-ft inundation above permanent pool over available treatment area compared to average annual storm volume as described by Table 3.
3. Reduction of annual load is determined from combining treated and untreated portions of the flow.

6.7.4 Factors Affecting Pollutant Removal

Preliminary investigation of data obtained from the DPW indicates a general increase in pollutant concentrations below the SWTP. The loading rate assessments discussed above need to be further refined for specific site loadings.

As with any natural system, pollutant removal function of a treatment wetland may vary. Some of the factors affecting pollutant removal include characteristics of pollutant load, oxygen availability, temperature, pH, vegetation productivity, and characteristics of the microbial community and soils. Studies have shown fairly consistent removal of phosphorus by treatment wetlands, but nitrogen removal can be quite variable, particularly when considered for short durations only, such as for a single storm event. As hydrologic calculations are refined for Wilsons Creek, the potential for nitrogen removal in the proposed treatment wetlands should also be investigated.

Long-term pollutant removal is enhanced by plant uptake. Rates and extent of uptake vary substantially according to species. Extensive information is available in the literature, and should be investigated as the need arises. Plant harvesting is sometimes employed for "complete" removal of pollutants, but several studies indicate that the majority of pollutants are actually stored in the root zone (Pond, 1993). Therefore, complete removal and replanting of the site would be required to achieve this purpose. The associated maintenance costs are most likely prohibitive.

Monitoring of pollutant removal performance should be included with implementation.

6.8 Initial Cost

Wetland construction cost is estimated at $30,000-$50,000 per acre. This estimate generally applies to smaller sites. Since the total area of wetland creation for Wilsons Creek is quite large, some cost savings may be realized from economies of scale. However, other factors, such as extent of excavation, obtaining plants, and environmental audits may increase the overall cost.

Preliminary cost estimates are presented in Table 7. Long-term operations and maintenance costs are addressed in Section 6.10.

Table 7. Estimated Capital Cost for Wetland Construction for Upstream Wilsons Creek Treatment Wetlands (Sites 1-3 only, 80 acres as per Table 1).

Scenario	Approximate Annual TP Load Removed (lbs)	Capital Cost/lb P removal
Storm Treatment	2,070	\$1,159-\$1,932
Base Flow Treatment	190	\$12,548-\$20,913
Combined Treatment	2,260	\$1,061-\$1,769

Table 7 demonstrates that the marginal cost for a combined treatment system is better than either storm or base flow treatment systems. However, it is important to note that all calculations presented in this report are considered preliminary and only apply to the three most upstream sites. All calculations should be refined as described above for individual site conditions as well as temporal (namely seasonal) variability and expanded to include all five wetland sites. Likewise, it may be possible to construct fewer sites, while still retaining benefits to Wilsons Creek.

WWE also recommends these wetland treatment costs be compared against costs for other structural and non-structural Best Management Practices (BMPs) in the Wilsons Creek Watershed. For example, urban non-point source pollution has been identified as a leading cause of impairment to Wilsons Creek. Implementing space-limited structural BMPs throughout the City of Springfield, establishing riparian buffer zones near future development, street sweeping, or other "good house-keeping" practices may be cost-effective source controls. Likewise, agricultural BMPs, such as fertilization schedule management or fencing to keep animals out of the river, may reduce pollutant loads.

6.9 Permitting

Various permitting issues may arise:

- Threatened and endangered species.

- Flood plain impacts, from wetland creation and from potential diversion of base flow from the main channel. It is the understanding of WWE that Greene County has authority over activities within the flood plain.
- Section 404/jurisdictional wetlands.
  1. Would one or more 404 permits be needed for construction?
  2. Would the site(s) be considered jurisdictional wetlands and therefore require a permit for maintenance or modification?
  3. Potential for future permits if the site(s) is abandoned?
- Access and easements.
- NPDES stormwater permits. Costs associated with monitoring. WWE estimates monitoring costs of approximately $3,300 per site for three storm events per year. This estimate does not include laboratory fees, equipment, or coordination and reporting. If the systems are used for TMDL compliance, is monitoring required?

WWE recommends consultation with USACE, MoDNR, MDC, NRCS early in the design process.

6.10 Maintenance Requirements and Anticipated Cost

Long-term maintenance is essential to success of the project. A study of a stormwater treatment wetland after a ten-year period showed decreased pollutant removal. The reduction in performance was attributed to channelization, invasive species, degradation of berms, etc. (Schueler, 2000).

If sites are created with sediment forebays (as recommended by WWE), monitoring should be performed to determine a dredging schedule. Dredging, or mucking out of the forebay will most likely be required about once per year, whereas dredging of the wetland itself is probably on the order of 10-20 years (if a forebay is included). Excess sedimentation in a wetland can cause various adverse effects.

It is possible that treatment to prevent mosquito breeding will be necessary. WWE addressed these issues in a separate memo to you in April. Information will not be repeated here.

Maintenance activities may also include inspection of inlet and outlet structures for clogging or other malfunction. Regrading may be necessary in some areas if channelization occurs. Open water areas, particularly near outlets, should be frequently inspected for the presence of beavers. Construction of beaver lodges may block outlets and inundate the entire wetland.

The wetlands would be subject to some damage during extreme floods; this risk should be acknowledged.

According to the USEPA (1999), long-term annual operation/maintenance/replacement (O/M/R) costs may be estimated at 2 percent of construction costs. Initial estimates of long-term O/M/R costs are \$76,200 - \$127,000 per year based on construction of 127 acres (total construction, as per Table 1). Actual costs are highly site specific and depend on the adopted design approach. Cost estimates may be refined with improved estimates of sediment accumulation, etc.

Availability of plants and threats from invasive species should also be investigated. Since wetlands have not existed previously at these sites, cost of acquiring plants (for initial plantings and subsequent maintenance) may be substantial. Additional costs may be incurred during the establishment period (approximately 3 to 5 years) of the wetland habitat, when frequent inspection and maintenance is critical to survival of a wetland ecosystem. Soil studies from the Des Plains River Restoration Project indicated that five years were required to fully develop hydric soils throughout the system. WWE experience indicates that annual replacement of 10-20 percent of initial plantings is necessary during establishment. Representative vegetation cost is \$1.50 per plant, and density is 4,840 plants per acre. Therefore, revegetation is estimated at \$61,000 - \$122,000 per year, based on 84 acres of vegetated wetland area, as per Table 1.

6.11 Public Perception/Reaction

Several issues have arisen with regard to potential public reaction:

1. Health and safety; for example, the potential for mosquito breeding.
2. Creation of wetlands in an area that did not historically support such an ecosystem. It is important that the goals of the project are clearly stated such that the public does not perceive the intention to re-create wetlands that were not historically there. How well will the constructed systems fit into the natural landscape of Springfield?
3. Impacts to private property from migratory birds. Wetlands create habitats suited to ducks, geese, and other migratory waterfowl.
4. Recognition that it may require several years before wetlands mature and water quality improvement may be recognized by the "casual" observer.
5. Potential adverse comments from property owners near the wetlands, including suggestions of decreased property value.

On the other hand, wetlands can be designed to incorporate public activities. For example:

1. Wetlands are frequently studied in schools.
2. Design can include walking/biking/running trails, picnic areas, and other recreational activities. These goals coincide with plans for the Wilsons Creek-South Creek Greenways.
3. Aesthetic improvements.

Discussion with MoDNR is encouraged to investigate these opportunities.

6.12 Utilities

Mapping of utilities was provided on a large-scale aerial photo provided by the City of Springfield. Sewer lines appear to transverse Sites 1–4. Electric utilities are potentially shown in Sites 1, 3, and 4. The extent of these utilities was not determined in detail; relocation requirements, options and constraints should be investigated in more detail. Utility relocation does not appear to be a significant issue.

7.0 CONCLUSIONS

This initial engineering investigation indicates that the creation of wetlands along Wilsons Creek in the Springfield area offers potential for significant improvement of water quality. The idea has merit and warrants further study. Refining the evaluation for specific site loadings, expansion to include the potential for nitrogen removal, and site configurations is the next logical step. WWE recommends joint treatment of base flow and stream flows, based on our current analysis. Site geotechnical analysis and refined hydrologic analysis are immediate needs, should feasibility studies continue. Conversations should be initiated with the Missouri Department of Natural Resources, Greene County, Missouri Department of Conservation, the U.S. Army Corps of Engineers, and the Natural Resources Conservation Service to discuss project goals, permitting and to encourage widespread approval. Additional data sources have been identified which may contribute to the analysis. The combined results of refined study should be geared towards creation of a pilot wetland, which would be used to refine design parameters for additional treatment areas.

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